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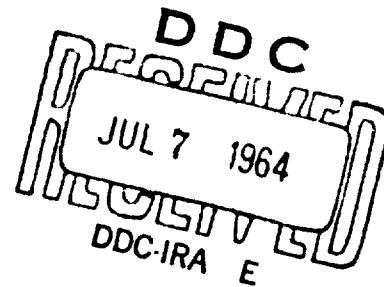
CRDLR 3194

Ballistic Studies in Eye Protection

by

Richard L. Williams
George M. Stewart

November 1963



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November 1963

CRDLR 3194

BALLISTIC STUDIES IN EYE PROTECTION

by

Richard L. Williams
George M. Stewart

Biophysics Division

Recommending Approval:



JOSEPH R. BLAIR
Colonel, MC
Director of Medical Research

Approved:



S. D. SILVER
Technical Director

U. S. Army Edgewood Arsenal
CHEMICAL RESEARCH AND DEVELOPMENT LABORATORIES
Edgewood Arsenal, Maryland

FOREWORD

This study was performed under Project 4C99-02-002, Wound Ballistics (U). It was supported by the U. S. Army Materiel Command and the U. S. Army Medical Corps. This work was started in January 1961 and completed in August 1962. The experimental data are recorded in notebook MN-986.

Acknowledgment

The authors express appreciation and gratitude to Sp/4 Duane Fandrem and Pfc. Gerald Cooper for their interest and professional and technical assistance in the conduct of these experiments.

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In conducting the research reported herein,
the investigators adhered to the "Principles
of Laboratory Animal Care" as established by
the National Society for Medical Research.

DIGEST

This work was undertaken to evaluate ballistically the resistance to penetration of optical lenses and rabbit eyes by the lead and steel BB's (7.95 and 5.28 gr, respectively). Plastic CR39 lenses were tested, in addition to several types of glass lenses. These 57.0-by 44.0-mm oval lenses were of two base curvatures, 9 and 12 diopter, and three thicknesses, 2.5, 3.0, and 3.5 mm.

On the basis of the evaluations, it is concluded that:

The plastic lenses were the most resistant to both missiles. The 9-diopter lenses were, in general, superior to the 12-diopter ones, and the lead BB deformed against all lenses to varying degrees, while the steel BB deformed very little.

For tests with eyes, the ballistic limit for the steel BB was higher than that for the lead BB, which is the reverse order to that for lenses. Neither the lead nor the steel BB deformed upon striking the eye.

The unshielded eye, in some cases, may provide itself better protection against impacts by missiles below its ballistic limit than can be obtained from some lenses. Missile impacts below the ballistic limit of the eye, however, could cause injuries ranging from minor corneal contusions to internal structural damage.

Eye armor is a definite asset to the protection of eyes, and any optically suitable material possessing encouraging ballistic properties, such as plastic CR39, could be considered a valid candidate.

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BALLISTIC STUDIES IN EYE PROTECTION

I. INTRODUCTION.

To maintain maximum combat efficiency of military personnel, protection for the prevention of injury to eyes should be included in any personnel armor program. Many government military agencies have concurred with this idea, and interest in such a program has been active since World War II.

During World War II, 7.8% of all aircrew casualties were caused by secondary fragments. Of these casualties, plexiglass fragments were the third most common cause. An analysis of 1,117 aircrew casualties from all types of missiles showed 19.8% had wounds of the head, of which a sizable number constituted eye injuries. For many of these eye injuries the causative agent also was plexiglass, which seldom caused injury to any other part of the body, and then produced only superficial wounds and lacerations.¹

A survey of 30,747 ground-force battle casualties occurring between August 1944 and May 1945 during World War II revealed that eye injuries as principal wounds amounted to about 2%.¹

Eye injuries accounted for 2.7% of the casualties in Korean action from June 1950 through December 1952. Among Army evacuees reported to the Surgeon General, as received in hospitals in the United States from Japan and Korea during the period 2 September 1950 through 31 March 1953, there were 145 cases of blinding involving both eyes and 1,071 cases involving one eye only. It has been estimated by Army ophthalmologists that over 50% of these eye injuries could have been prevented by eye armor.²

In 1954, work was started on the ballistic evaluation of eyes and lenses against different types of small high-speed missiles in these Laboratories.^{3,4} This work has been continued with two additional missiles—the lead and steel BB's.

Tests to determine the resistance of optical lenses to the above missiles have been conducted with five different types of lenses. Some of these types were manufactured by American Optical Company, while others were manufactured by Bausch and Lomb. The non-heat-treated glass and non-heat-treated glass (edged) lenses supplied by Bausch and Lomb and

American Optical Company, respectively, apparently differed only in the way the edges were ground (figure 1, appendix).

Tests to determine the resistance of eyes to penetration by these two missiles were conducted against excised rabbit eyes.

II MATERIALS AND EQUIPMENT.

- A. Excised rabbit eyes, 5 to 7 mo old.
- B. Sodium pentobarbital, syringes, surgical instruments.
- C. Gelatin blocks, 15 by 6 by 5 in.
- D. Lenses in two base curves, 9 and 12 diopter, 57.0- by 44.0-mm ovals. Thicknesses of each lens type were 2.5, 3.0, and 3.5 mm. Types evaluated were heat-treated glass, non-heat-treated glass, non-heat-treated glass (edged), plastic CR39, and laminated glass.
- E. Steel BB, 0.172-in. diameter, 5.28 gr
- F. Lead BB, 0.172-in. diameter, 7.95 gr
- G. Smoothbore gun tube, 0.187-in. round barrel (airshot), 8-1/2 in. long.
- H. Benjamin target air pistol, Model No. 130.
- I. Rolled, 3-in.-wide, black, adhesive, cloth tape.
- J. Helium gun.
- K. Two counter chronographs, Potter Model 456 pulser unit, silver-screen velocity-measuring apparatus.
- L. Velocity-measuring device with optical slit
- M. Remote-control firing box.
- N. Lens holder

III. METHODS AND PROCEDURE.

The lead BB and the steel BB were fired from either a Benjamin air pistol or a locally fabricated helium pressure gun. The gun muzzle was placed approximately 2 ft from the sample, the velocity-timing screens were placed 6 in. in front of the sample, and a strong adhesive tape was placed 1 in. behind the lens to trap fragments and spallings thrown from the lens and to capture or determine the path of perforating missiles. The lenses were placed with the convex surfaces facing the gun. Accurate velocities were obtained with both guns by employing techniques set forth by earlier investigators.³⁻⁶

Ballistic limits of lenses and eyes against the lead and steel BB's were determined by computing the average of the five lowest complete-penetration velocities and the five highest partial-penetration velocities. These criteria are used to establish ballistic-limit V_{50} evaluations in these Laboratories.

Three methods were used to determine complete penetrations:

1. In the event of the slightest indication of spallings or the tiniest spicules being adherent to the collect-tape in back of the lens, the result was considered a complete penetration, because it is probable that some injury might be inflicted on the eye by minute secondary missiles at relatively low velocities.

2. The end of the fingernail was drawn at right angles over the back of those lenses that still remained apparently intact to detect any roughness on the back or concave surface, which might indicate secondary missiles driven from the lens.

3. Visual inspection of the back of the lens was made with the aid of a 5X magnifying eyepiece to detect spalling.

During the experiments, lenses of the two different manufacturers were not intermixed, and all shots were directed at the center of the lens under test.

Eyes used for these tests were excised from 5- to 7-mo-old rabbits that were first sacrificed with sodium pentobarbital injected intravenously.

The eyes were embedded in a hollowed-out socket in one face of a gelatin block (figure 2, appendix) and placed 34 in. from the muzzle of the gun. Tests were then begun immediately with all rounds aimed at the center of the cornea.

Visual examination was used to distinguish between defeat of the missile by the eye (partial penetration) and defeat of the eye by the missile (complete penetration). The standards used to differentiate between partial and complete penetrations of the rabbit eye were as follows:

1. When fluid is lost from the anterior and/or posterior chambers after impact, it is a complete penetration.
2. When no fluid escapes after an impact, it is a partial penetration.

Upon complete penetration of an eye, firing at that particular eye was discontinued. More than one round was fired at eyes for which there were partial penetrations, however, until the eye became unsuitable for further testing as a result of flabbiness because of loss of fluid from around the optic nerve or internal structural damage.

IV. RESULTS.

During these tests, for similar areas hit at comparable velocities, similar fracture patterns were produced for a particular type of lens. However, these fracture patterns differed from type to type (figures 3 to 6, appendix). Fractures ranged from slight to extensive, but separation of the pieces was not effected in all cases.

Laminated lenses presented a fracture pattern that can probably be attributed to the binding layer between the two glass layers (figures 5 and 6, appendix).

Fragments from the five types of lenses varied in size and shape from minute needlelike spears or splinters to larger irregularly jagged pieces, as shown in figure 7, appendix. Although this is true, fragments from plastic lenses were not as numerous or as sharp as those from glass lenses.

The lead and steel BB's sometimes left petalled circular scars on some lenses after partial penetrations, as portrayed by figure 8, appendix. The clear central foci from which radiating lines extend to the periphery of the scars compare closely to the patterns on the impact surfaces of the lead BB's in figure 9, appendix.

U. S. Army Edgewood Arsenal
CHEMICAL RESEARCH AND DEVELOPMENT LABORATORIES
Edgewood Arsenal, Maryland

ERRATUM SHEET

Report No.: CRDLR 3194

Title: BALLISTIC STUDIES IN EYE PROTECTION

Authors: Richard L. Williams
George M. Stewart

Date: November 1963

This report was forwarded to your installation on 17 December 63.

On page 2, under the first paragraph of the FOREWORD,
add the following paragraph:

"The research reported herein was performed under the
immediate supervision of a qualified biological scientist. The research
conforms to the provisions of AR 70-18 and the appendix thereto."

For Florence C. Burnett
LOUISE M. DELSASSO
Chief, Publications Section
Technical Releases Branch
Technical Information Division

Approximately 72% of tests indicated that 9-diopter lenses offered more resistance to penetration than did the 12-diopter lenses of the same thicknesses, as shown in table 1. Of 51 tests, during which 542 lenses were evaluated, 58.8% showed an increase in ballistic limit with an increase in lens thickness. As noted in table 1, however, some ballistic limits were lower for thick lenses than for thinner lenses. For the plain-glass and heat-treated-glass lenses, this may be attributed to the inherent variations in stress patterns as a result of the manufacturing process. Even though the plastic and laminated lenses showed a few of these same discrepancies, they generally behaved as might be expected (ballistic limit increased as lens thickness increased). Although the plain-glass and plain-glass (edged) lenses seemed to differ only with respect to the ground edges, ballistically they differed significantly (table 1). A limited supply of lenses necessitated minimum testing to obtain these ballistic limits, and more exhaustive firing may have produced a more linear pattern in results.

Test findings show that plastic lenses offered more resistance to penetration (for comparable thicknesses) than did other types, with the exceptions of some heat-treated lenses (table 1).

The ballistic limits for lenses tested against the steel BB were without exception lower than those for lenses tested against the lead BB. This was because much of the striking energy of the lead BB was absorbed during its deformation.

Deformation of the lead BB was pronounced after impacting lenses at various velocity levels. This deformation varied from slight flattening on the impact surface at low velocities to "pancake" flattening and disintegration at high velocities. The steel BB, by contrast, was only slightly deformed even at high missile speeds. Figure 9, appendix, shows some of these differences in deformation produced by heat-treated-glass lenses.

The differences between ballistic limits for the lead and steel BB's versus various lenses ranged from 69 to 273 ft/sec.

The ballistic limit of the steel BB versus the eye was 249 ft/sec and that for the lead BB was 212 ft/sec, which is a reversal of the pattern observed for these two missiles against lenses. Because the mass of the lead BB is greater than that of the steel, the inertia of the heavier sphere overcame the resistance of the eye more easily at comparable speeds. Also, energy lost in deformation of the lead BB when striking a lens does not occur with the eye, thereby contributing to this greater facility of penetration.

TABLE

BALLISTIC LIMITS OF PLATES
VERSUS STEEL AND

Lens	Lens thickness	9-Diopter lenses	
		Steel	Aluminum
	mm		
Heat-treated glass	2.5	178	—
	3.0	235	—
	3.5	199	—
Plain glass	2.5	101	—
	3.0	93	—
	3.5	124	—
Plain glass (edged)	2.5	— *	—
	3.0	125	—
	3.5	118	—
Plastic CR39	2.5	287	—
	3.0	281	—
	3.5	397	—
Laminated glass	2.5	119	—
	3.0	131	—
	3.5	— *	—

* No lenses available.

LE 1

PROTECTIVE LENSES
AND LEAD BB'S

lens versus BB's		12-Diopter lens versus BB's
Lead	Steel	Lead
ft/sec		
397	216	394
437	200	473
448	278	542
257	-*	160
204	-*	-*
336	-*	-*
210	80	293
347	88	323
379	111	351
383	228	297
523	256	355
571	272	463
217	97	186
226	80	294
-*	105	-*

On some of the shots that were partial penetrations, the missiles did not strike the center of the cornea, but struck it a glancing blow. Sometimes it was difficult to observe the point of impact with the naked eye, but frequently gross evidence of impact was indicated by the tearing and distortion of the iris, and flat circular impressions were seen on the cornea with the aid of a magnifying lens. For partial penetrations close to the center of the cornea, the point of impact also presented a flat circular area that appeared to be slightly sunken, with approximately 0.1-mm-high edges. As with the glancing corneal impacts, some of the centered impacts caused stretching, dislocation, and tearing of the iris (figure 10A, appendix).

For some partial penetrations, vitreous humor was forced out the back of the eye through the thin connective tissue around the optic nerve and vascular attachment. The hole in the sclera may be seen in figure 10B, appendix. This phenomenon caused the eye to become flabby and no longer suitable for valid testing.

On occasions, the missile did not completely perforate the eye, but remained lodged within, as seen in figures 10C and 10D, appendix. Sometimes the missile would lodge in the anterior chamber in front of the lens, where it appeared near normal in size, while it was magnified approximately 3X if it came to rest in the posterior chamber, behind the lens.

When cubes were fired, the missile was often rejected after penetration of the eye.³ No direct observations were made during this series of tests of spherical missiles puncturing the cornea and being rejected.

Once the missile penetrated the cornea, if it entered the eye in the area of the iris, this structure would be damaged (figure 10D, appendix). If the lens were struck, it would also be damaged.

Holes in the cornea were not large gaping ones, but were usually about the diameter of the missile. Often these holes had irregular edges (figure 11A, appendix). Figure 11B, appendix, shows the exit hole of the eye in 11A.

Sometimes the missile would miss the cornea altogether, but would strike and penetrate the sclerocorneal junction or the sclera posterior to this junction. This would render the eye invalid for further testing, since flabbiness would result from loss of fluid (figure 11C, appendix).

There was no noticeable deformity to either of the missiles when tested against the eye.

V. DISCUSSION.

For some partial penetrations, the eye would probably not be permanently damaged. For complete penetrations, immediate medical attention might result in saving the eye.^{7,8}

The tough, connective-tissue covering of the eye may provide better protection against impacts by small missiles than that afforded by some lenses. This can be based on the premise that there would be no secondary fragments striking the eye from defeated protective items placed in front of it.

If a lens having a ballistic limit higher than that for the eye is placed in front of the eye and struck by an object, similar to those tested, at a velocity less than the ballistic limit of the lens but greater than the ballistic limit of the eye, the eye would be spared corneal abrasion, ocular damage, and hemorrhage caused by partial penetration of the lens. Thus, the missile would be defeated by the lens. In this respect, the lens would afford the eye protection. The unshielded eye, however, could afford itself more protection than a lens against a missile whose velocity is above the ballistic limit of the protecting lens (defeat of the lens) and below the ballistic limit of the eye. In such a case, the eye would probably suffer less damage from a primary missile striking it than from fragments knocked from a broken lens.

For eye protection against fragments, particles, or missiles with configurations, masses, and consistencies similar to the steel BB, the ballistic limit of any artificial device or lens must be above 240 ft/sec (ballistic limit for the steel BB versus the eye). Such a device would suffice for protection against objects with configurations, masses, and consistencies similar to the lead BB, since the ballistic limit of the eye against this missile is approximately 37 ft/sec lower than that for the steel BB. Table 2 lists the ballistic limits of lenses tested that are higher than the ballistic limit of the rabbit eye against the steel missile.

The data in table 2 show that the eye would be guaranteed protection against severe injury or loss from small objects striking these protective devices at velocities below their ballistic limits.

TABLE

**BALLISTIC LIMITS OF LENSES PR
AGAINST STEEL A**

Lens	Lens thickness	9-Diopter lens	
		Steel	mm
Plastic	2.5	287	
	3.0	281	
	3.5	397	
Plain glass	2.5	—	
	3.0	—	
	3.5	—	
Plain glass (edged)	2.5	—	
	3.0	—	
	3.5	—	
Heat-treated glass	2.5	—	
	3.0	—	
	3.5	—	
Laminated glass	2.5	—	
	3.0	—	
	3.5	—	

* Below ballistic limit of rabbit eye versus steel

LE 2

PROVIDING PROTECTION TO EYE AND LEAD BB'S

lens versus BB's		12-Diopter lens versus BB's
Lead	Steel	Lead
ft/sec		
383	-*	297
523	256	355
571	272	463
257	-	-
-*	-	-
336	-	-
-*	-	293
347	-	323
379	-	351
397	-*	394
437	-*	473
448	278	542
-	-	-*
-	-	294
-	-	-*

steel BB (249 ft/sec).

Not all impacts from objects similar in shape and weight to those tested would inflict permanent injury to the eye. Injury would be of varying degrees, depending upon impact velocities, area struck, extent of damage, and whether loss of fluids resulted. Some partial penetrations would, at most, cause a bloodshot condition (contusion), whereas others might damage and rupture internal components of the eye, even though the cornea has not been punctured. More extensive damage and greater chance of eye loss could result from complete penetrations.

There are several requirements for a suitable eye-armor material. Some of the criteria for a candidate are that it will:

1. Conform to facility and economy of production.
2. Be easy to clean.
3. Resist scratching.
4. Possess good antifog properties.
5. Have durable optical qualities.
6. Transmit 90% of radiant light.
7. Have a ballistic limit considerably above that of the eye.
8. Be compatible with other equipment (especially military).

Such an eye armor can be a vital asset in the prevention and decrease of major eye injuries and losses to military personnel operating in the field under combat conditions and to industrial personnel in their respective areas of employment.

VI. SUMMARY.

Lead and steel BB's were fired at rabbit eyes and five types of optical lenses at velocities ranging from 40 to 611 ft/sec. Each type of missile, at comparable velocities, produced fracture patterns that were somewhat different from lens type to lens type, but were similar for lenses of the same type. Fractures ranged from slight to extensive and fragments varied from minute splinters to large jagged pieces.

Scars were sometimes produced on lenses after partial penetrations by lead BB's that compared closely to patterns on the impact faces of these missiles.

Only in 58.8% of the lenses tested did the ballistic limit increase with increase in lens thickness. Ballistic limits were lower for lenses tested against the steel BB than for those tested against the lead BB. This is attributed to the considerable amounts of energy lost in deformation of the lead BB, while the steel missile deformed very little, thereby retaining more of its kinetic energy.

In 72% of the tests the 9-diopter lenses offered more resistance to both missiles than did the 12-diopter lenses. Plastic lenses offered more resistance to these missiles, with the exception of five groups of heat-treated lenses, than did the glass lenses.

In the evaluation of eyes from 5- to 7-mo-old rabbits, the ballistic limit for the eye against the steel BB was higher than that for the lead BB. This is a reverse pattern to that for lenses. This phenomenon is attributed to the greater mass of the lead BB and its failure to deform.

Because of the greater flexibility of the tissues of the eye as compared with artificial lenses, impacts caused no deformity to either the lead or steel BB.

Partial-penetration impacts on the eye caused scars on the cornea, penetration of the cornea, distortion and tearing of the iris, damage to the lens, and loss of ocular fluids from around the optic nerve; loss of fluid from the anterior and/or the posterior chamber indicated complete penetrations.

VII. CONCLUSIONS.

On the basis of the evaluations, it is concluded that:

The plastic lenses were the most resistant to both missiles. The 9-diopter lenses were, in general, superior to the 12-diopter ones, and the lead BB deformed against all lenses to varying degrees, while the steel BB deformed very little.

For tests with eyes, the ballistic limit for the steel BB was higher than that for the lead BB, which is the reverse order to that for lenses. Neither the lead nor the steel BB deformed upon striking the eye.

The unshielded eye, in some cases, may provide itself better protection against impacts by missiles below its ballistic limit than can be obtained from some lenses. Missile impacts below the ballistic limit of the eye, however, could cause injuries ranging from minor corneal contusions to internal structural damage.

Eye armor is a definite asset to the protection of eyes, and any optically suitable material possessing encouraging ballistic properties, such as plastic CR39, could be considered a valid candidate.

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APPENDIX

FIGURES

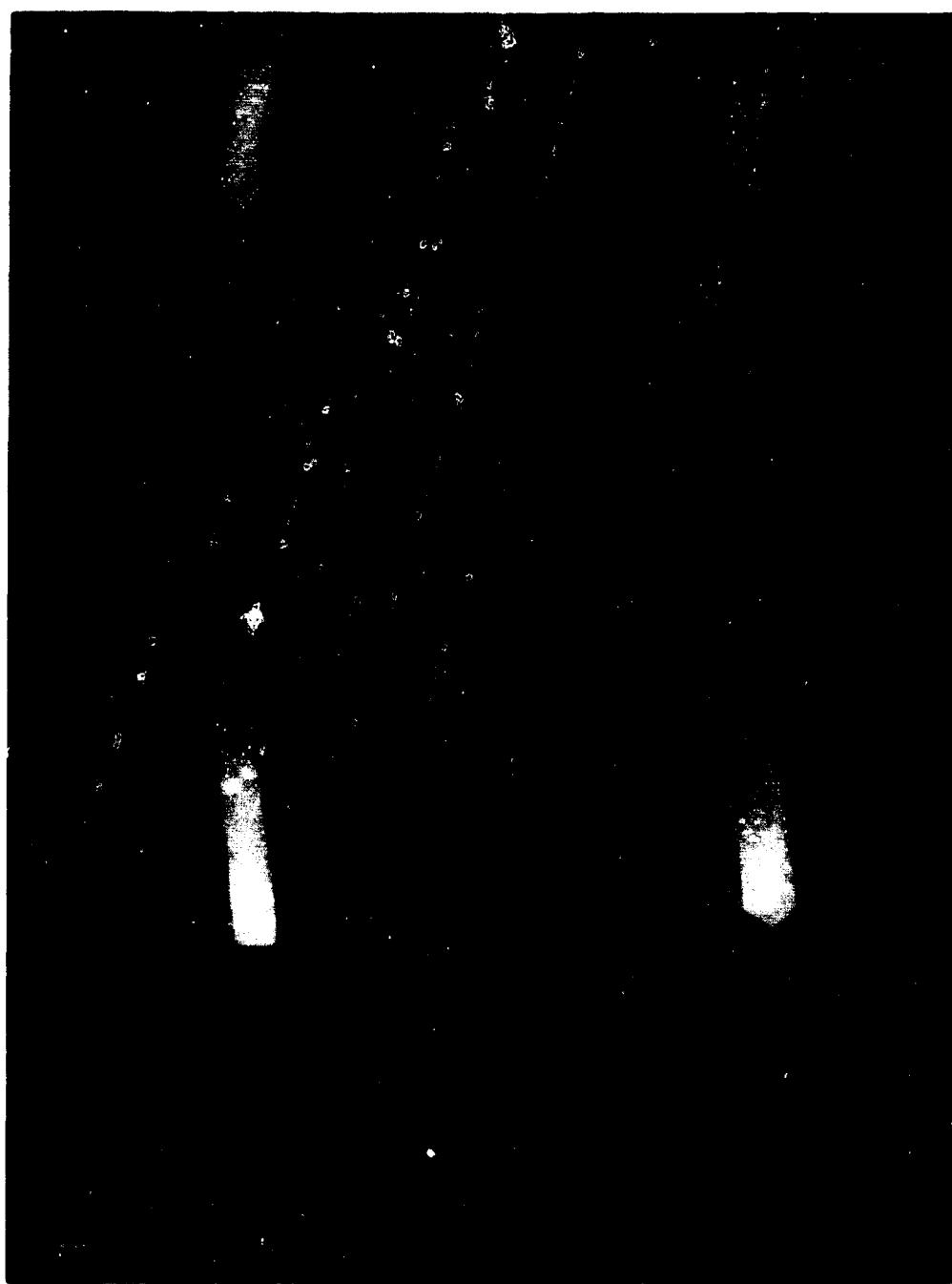


FIGURE 1

PLAIN-GLASS LENSES

Left: 9-Diopter, 3.0-mm lens with flat edge

Right: 12-Diopter, 3.0-mm lens with V-beveled edge



FIGURE 2
RABBIT EYE MOUNTED IN GELATIN BLOCK

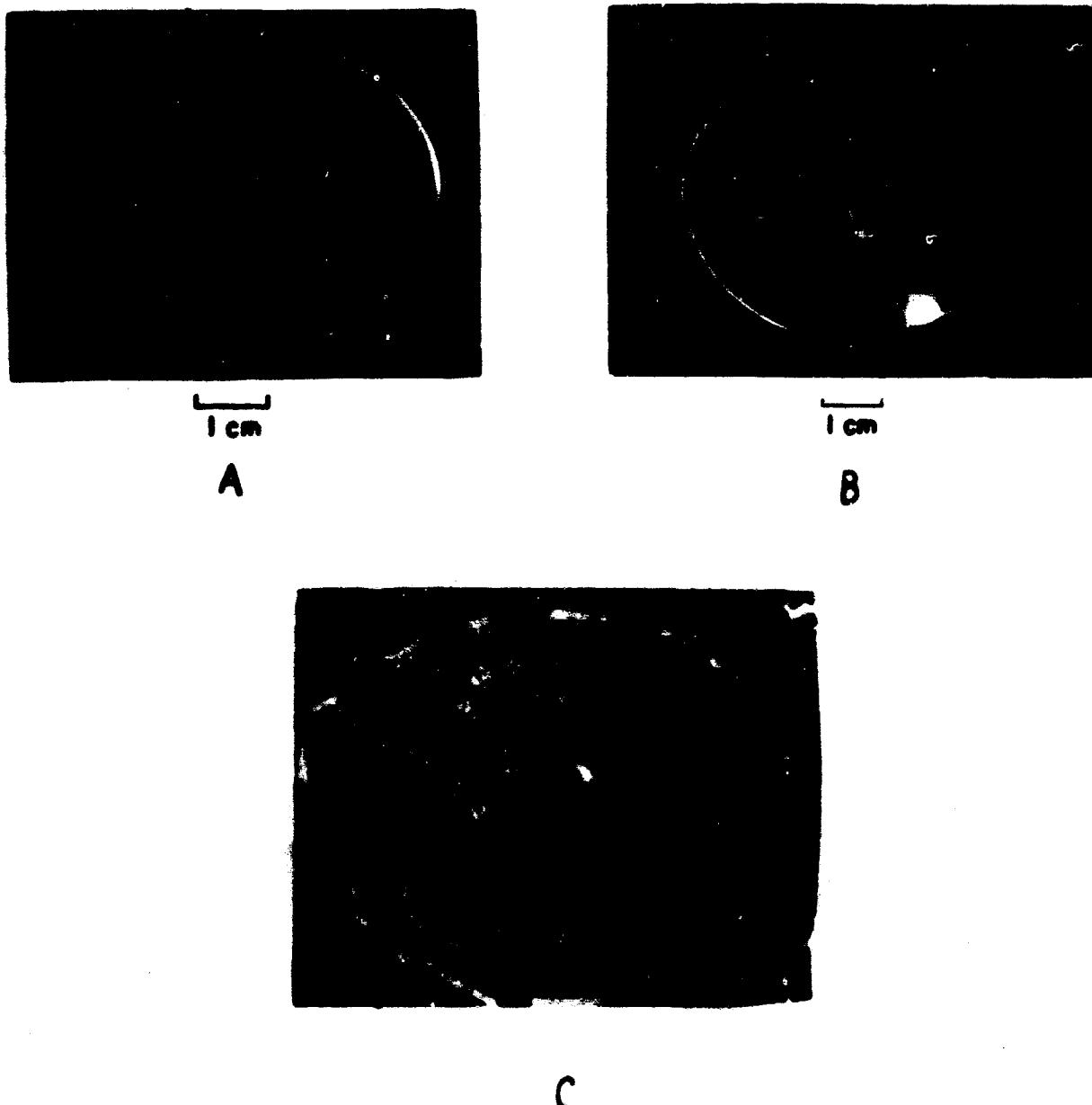


FIGURE 3

TYPICAL FRACTURE PATTERNS

- A. 9-Diopter, 3.0-mm plain-glass lens versus steel BB at 104 ft/sec; lens struck in center
- B. 9-Diopter, 3.0-mm plain-glass lens versus lead BB at 207 ft/sec; lens struck slightly off center
- C. 12-Diopter heat-treated-glass lens versus steel BB at 284 ft/sec; lens struck in center

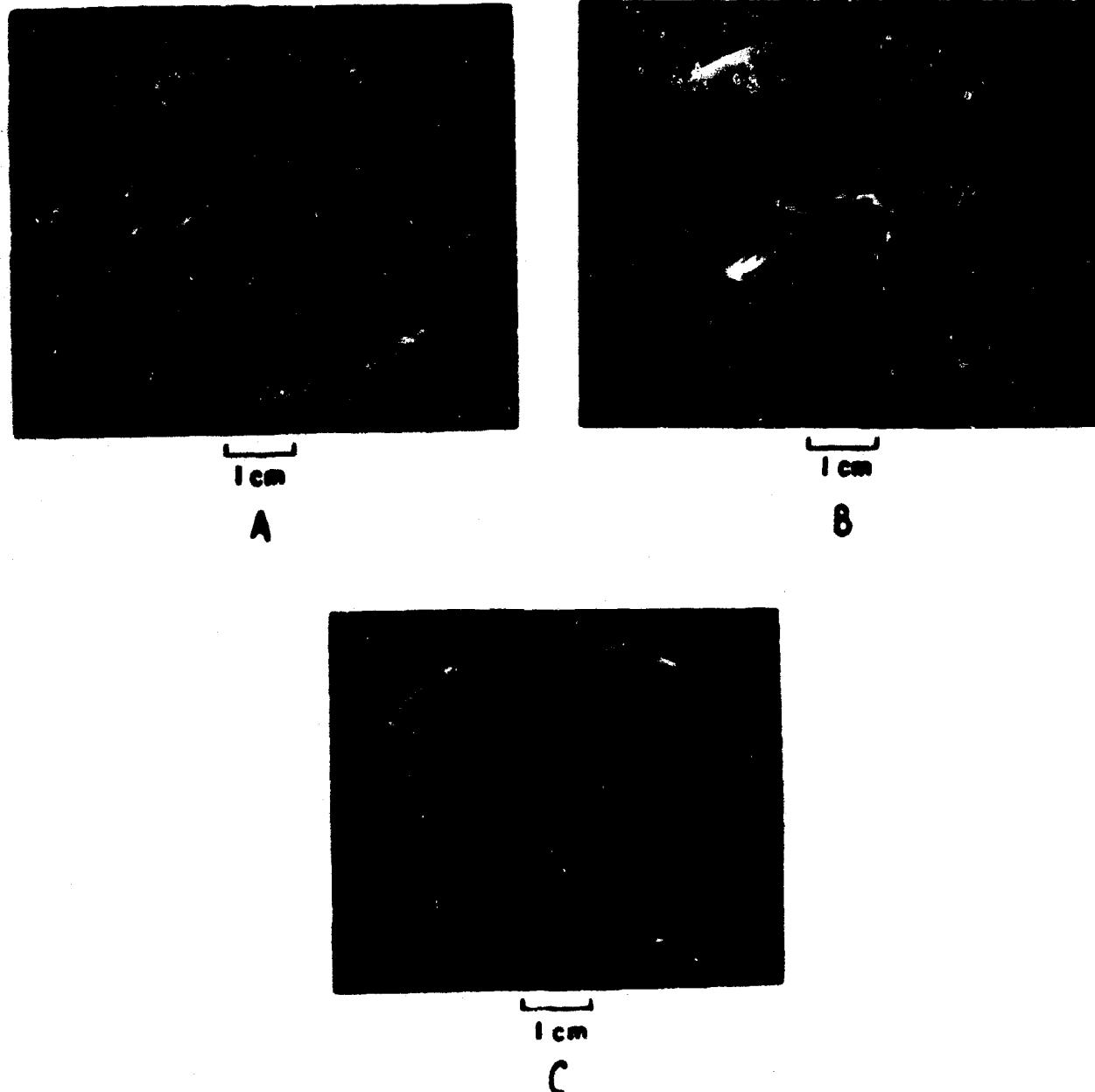


FIGURE 4
**FRACTURE PATTERNS OF PLASTIC LENSES IMPACTED
BY STEEL BB**

- A. 12-Diopter, 3.5-mm lens impacted at 260 ft/sec. lens struck near edge
- B. 12-Diopter, 3.5-mm lens impacted at 267 ft/sec. lens struck in center
- C. 9-Diopter, 2.5-mm lens impacted at 283 ft/sec. lens struck slightly off center

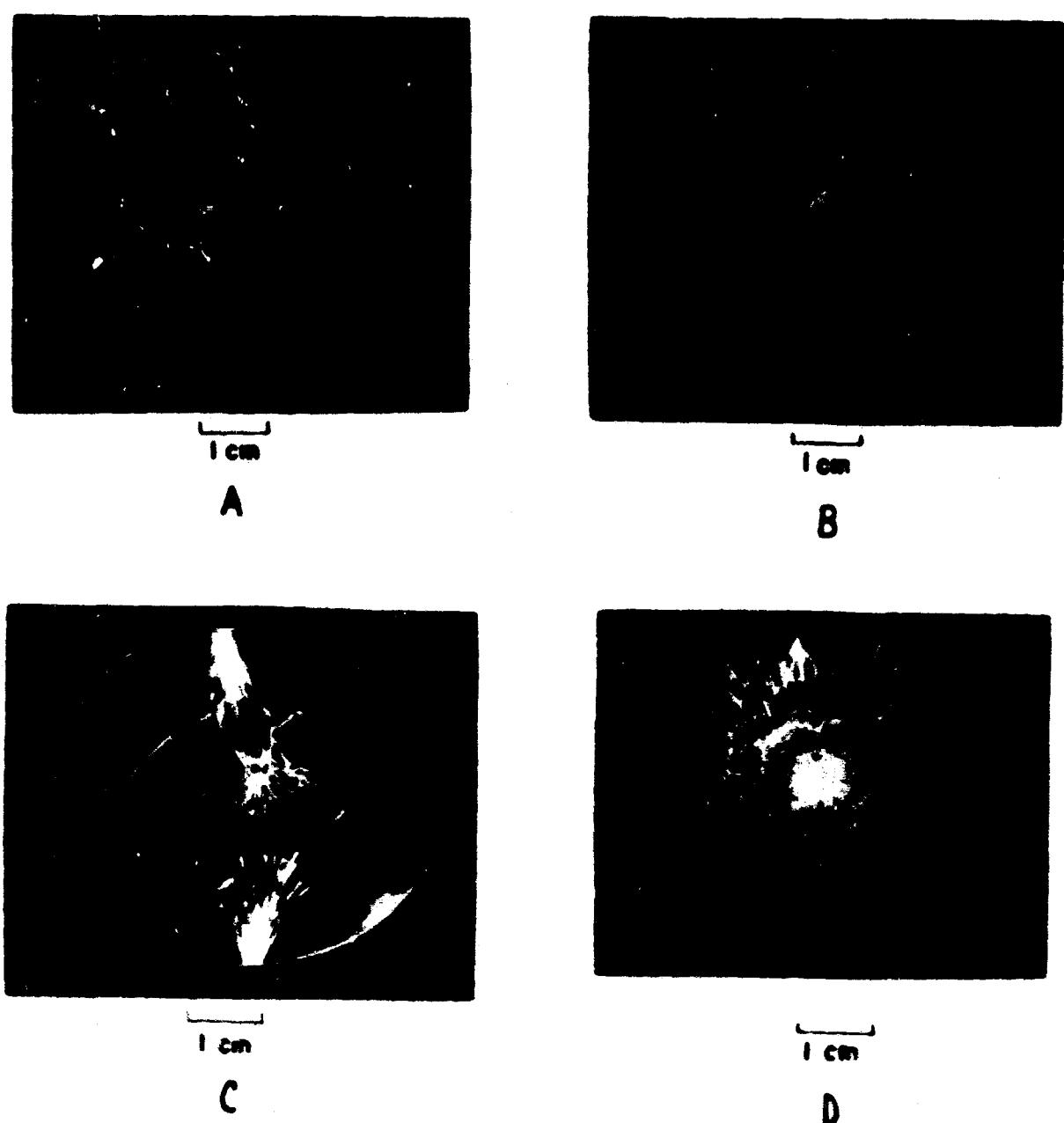


FIGURE 5

FRACTURE PATTERNS OF 9-DIOPTER, 2.5-MM LAMINATED-GLASS LENSES IMPACTED BY LEAD BB

A. 201 ft/sec B. 244 ft/sec

C. 283 ft/sec D. 351 ft/sec



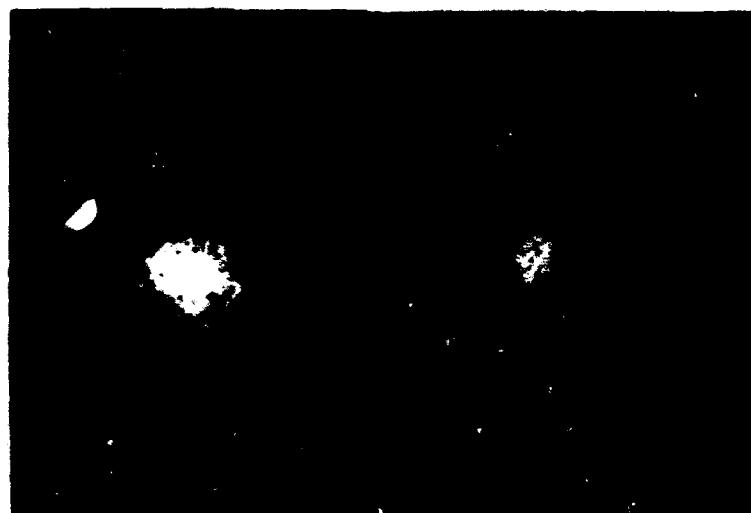
1 cm

A



1 cm

B



1 cm

C

FIGURE 6

FRACTURE PATTERNS OF 9-DIOPTER, 2.5-MM LAMINATED-GLASS LENSES IMPACTED BY STEEL BB

A. 115 ft/sec

B. 95 ft/sec

C. 264 ft/sec

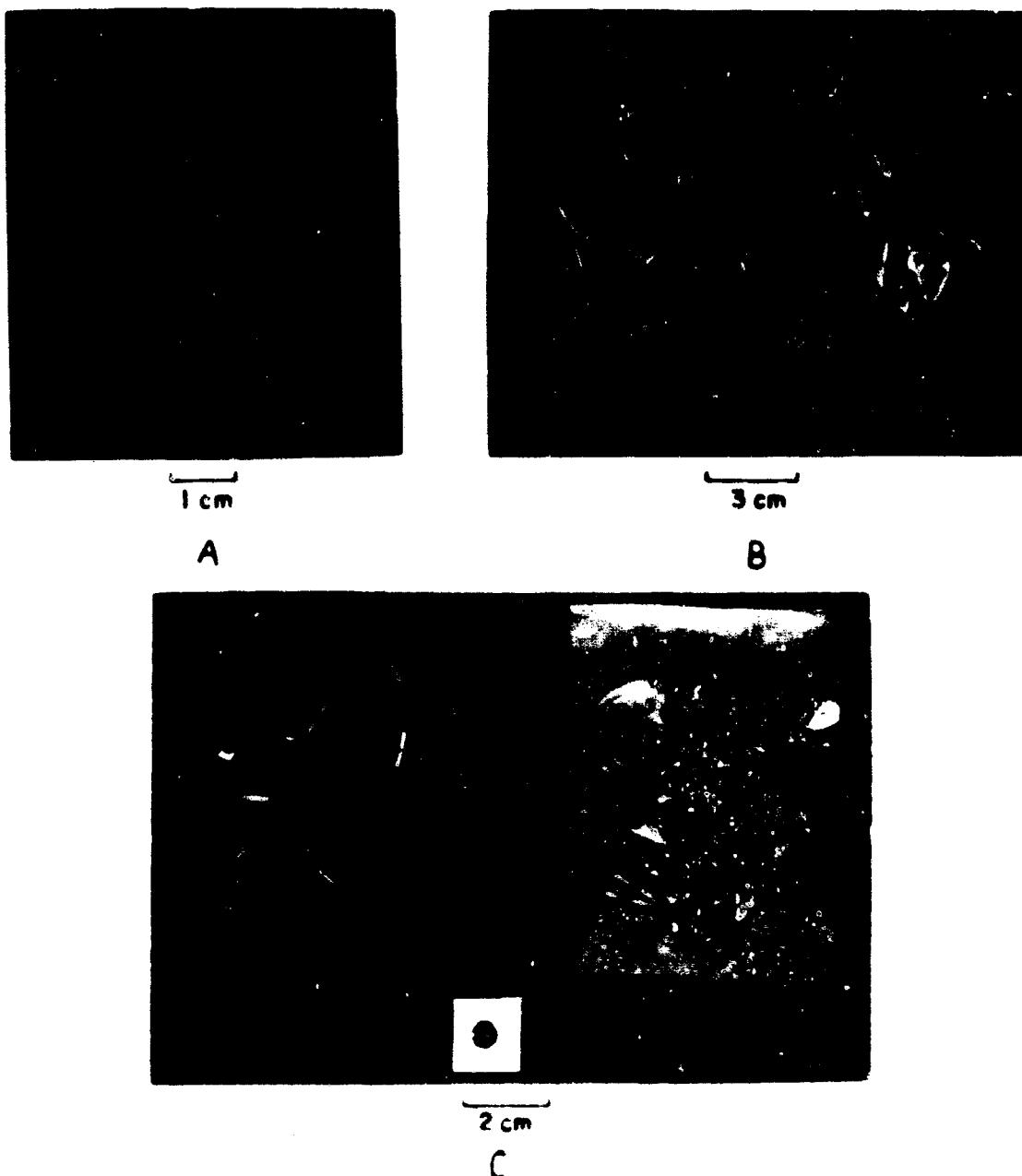


FIGURE 7

**SPALLINGS AND FRAGMENTS FROM FRACTURED LENSES
RECOVERED ON TAPE**

- A. 12-Diopter, 3.0-mm heat-treated-glass lens versus steel BB at 208 ft/sec
- B. 9-Diopter, 2.5-mm plain-glass (edged) lens versus steel BB at 212 ft/sec; arrow shows missile trapped by tape
- C. 12-Diopter, 2.5-mm plain-glass lens versus lead BB at 265 ft/sec, impacting missile at bottom of photo

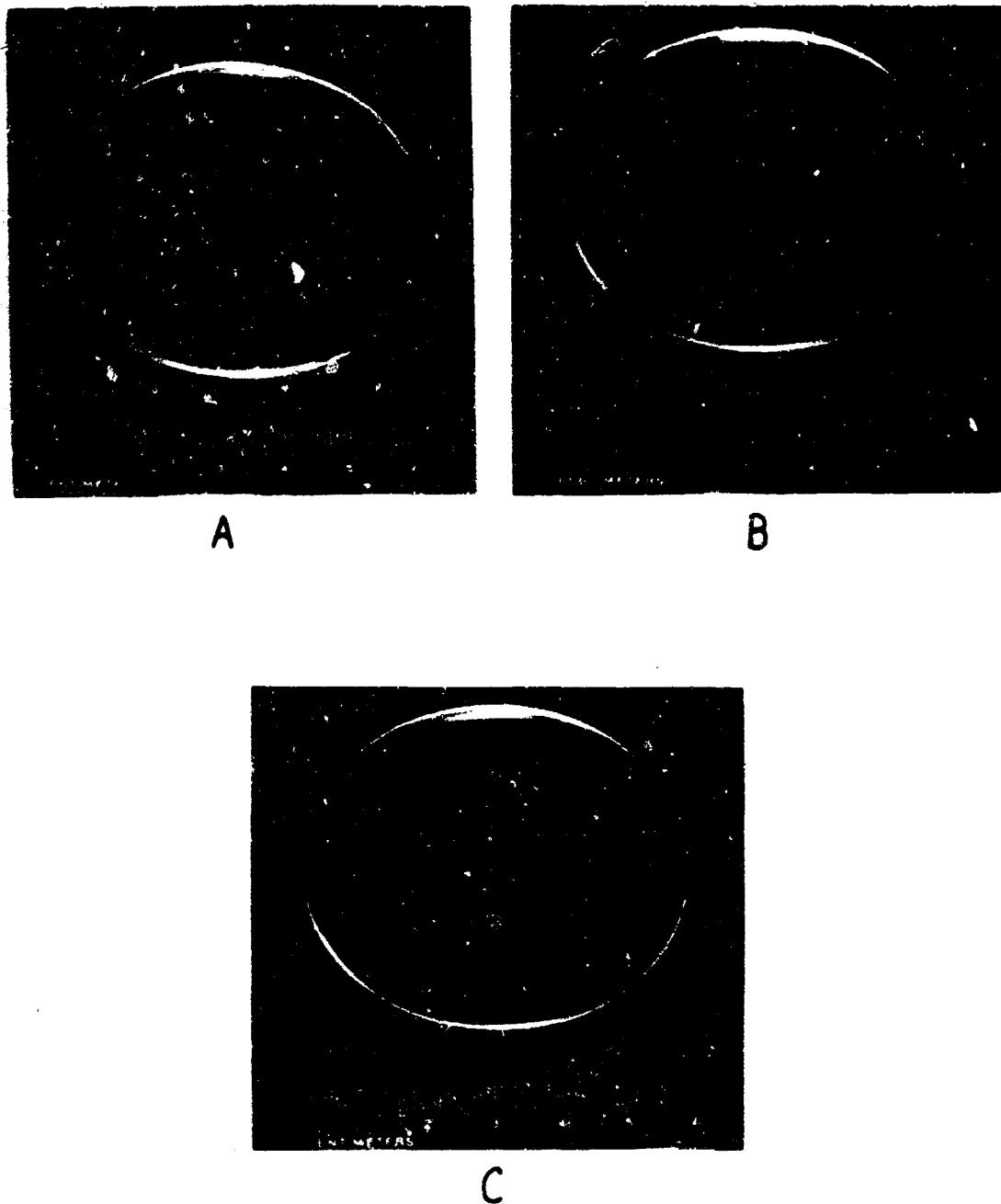


FIGURE 8

PETALLED SCARS ON LENSES AFTER PARTIAL PENETRATIONS
BY LEAD AND STEEL BB'S

- A. 9-Diopter, 3.0-mm laminated-glass lens impacted at 41 ft/sec by steel BB
- B. 9-Diopter, 2.5-mm laminated-glass lens impacted at 218 ft/sec by lead BB
- C. 9-Diopter, 2.5-mm plain-glass (edged) lens impacted at 201 to 213 ft/sec by lead BB's

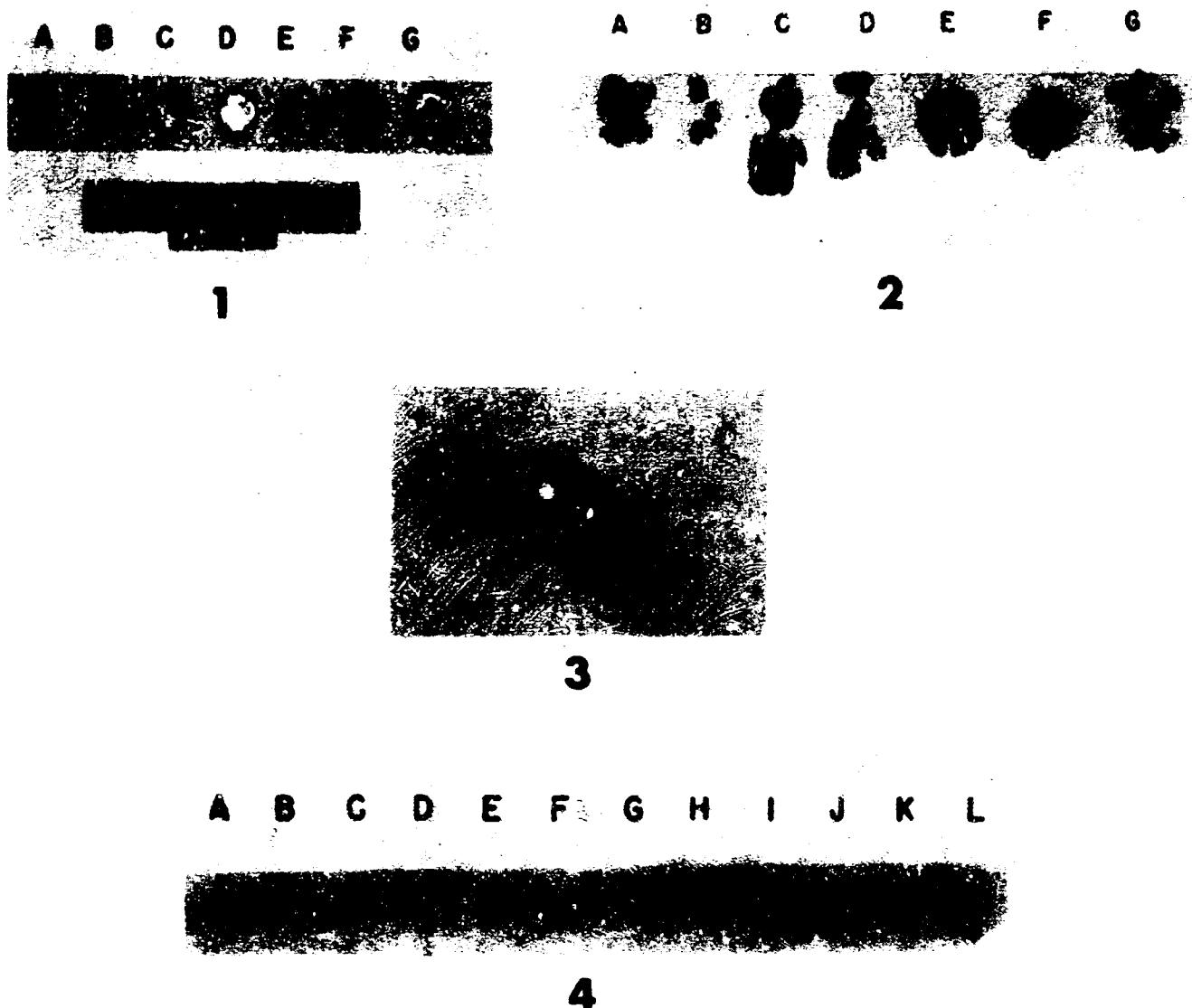


FIGURE 9

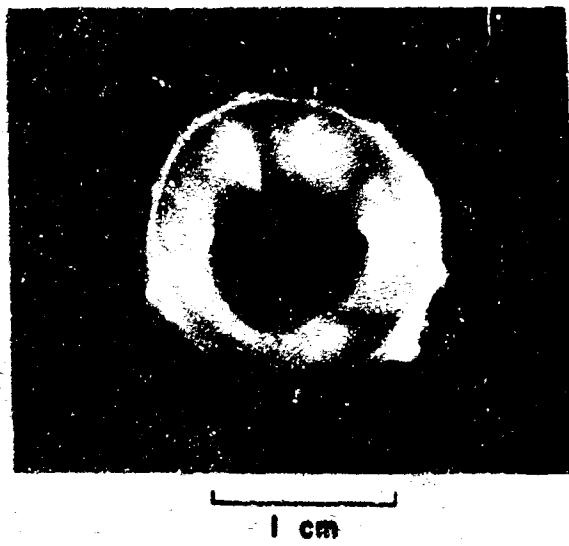
MISSILE DEFORMATION AFTER IMPACTING 12-DIOPTER
HEAT-TREATED-GLASS LENSES

1. Lead BB's versus 2.5-mm lens at following velocities, ft/sec

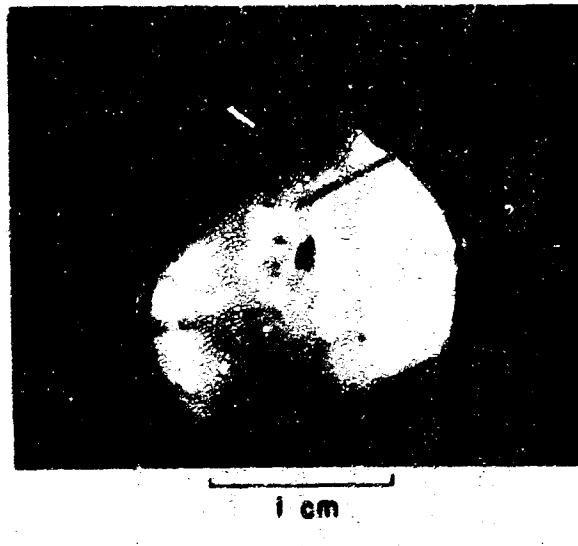
A. 172	C. 240	E. 358	G. 379
B. 215	D. 293	F. 371	
2. Lead BB's versus 3.5-mm lens at following velocities, ft/sec

A. 507	C. 551	E. 552	G. 598
B. 543	D. 551	F. 555	
3. Enlarged steel BB versus 3.5-mm lens at 263 ft/sec; arrow points to deformation
4. Lead BB's versus 3.5-mm lens at following velocities, ft/sec

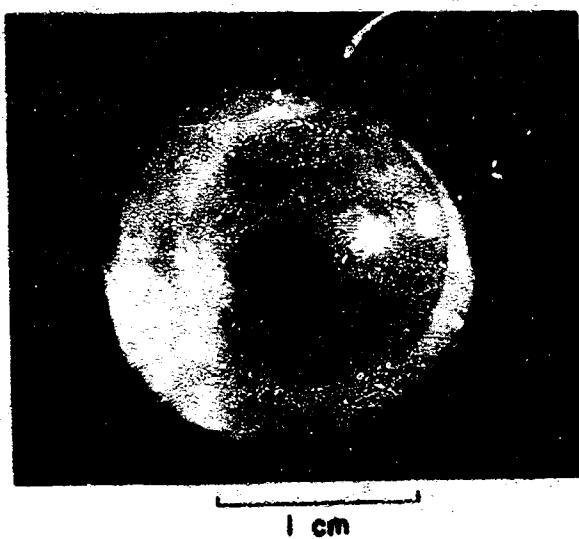
A. 168	D. 240	G. 343	J. 381
B. 188	E. 272	H. 353	K. 389
C. 232	F. 293	I. 360	L. 416



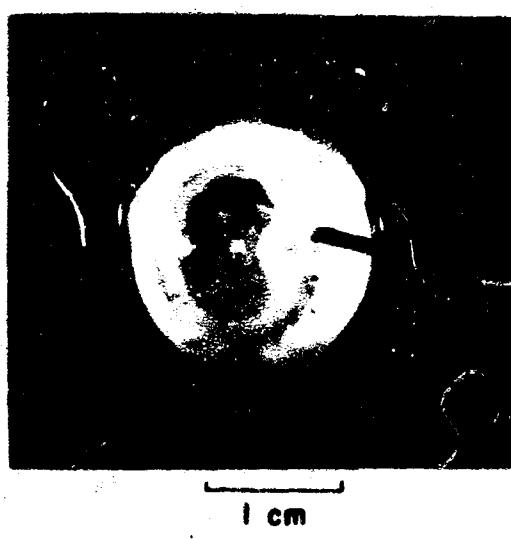
A



B



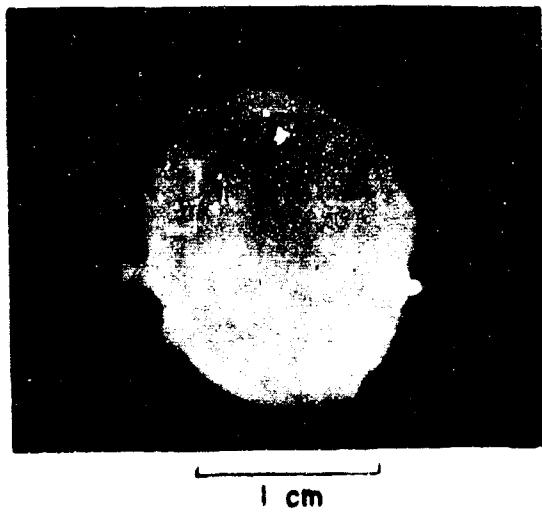
C



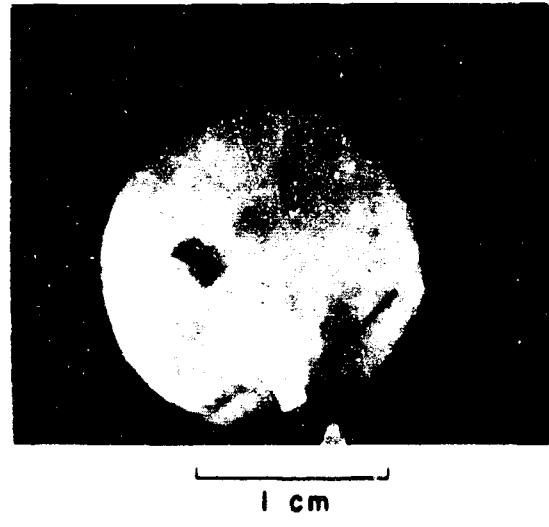
D

FIGURE 10
LEAD BB'S VERSUS RABBIT EYES

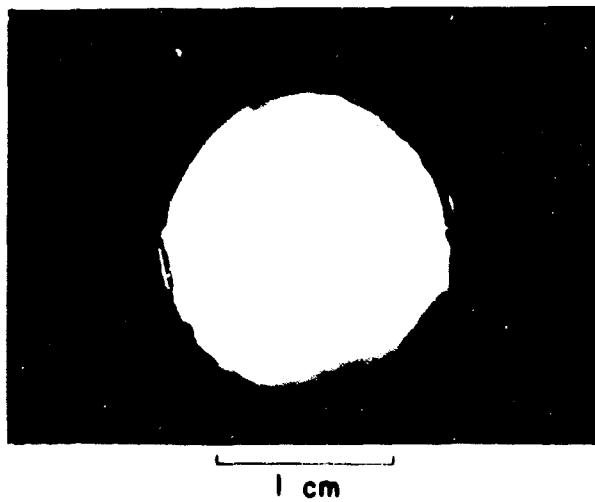
- A. Torn and convoluted iris resulting from partial penetration (eye in gelatin)
- B. Hole near optic nerve from which vitreous humor was forced after partial penetration (optic nerve at arrow)
- C. Lead BB resting in anterior chamber in front of lens after penetrating cornea
- D. Rupture of iris after penetration of eye at sclerocorneal junction; probe passes through entrance hole, behind lens, to posterior chamber; partially obscured lead BB (dark area at top of eye) behind end of probe lies in this chamber



A



B



C

FIGURE 11

LEAD BB'S VERSUS RABBIT EYES

- A.** Missile hole in center of cornea showing irregular edges
- B.** Back of eye in A, above, showing exit from sclera (optic nerve at arrow)
- C.** Hole in cornea at sclerocorneal sulcus showing emission of formalin-coagulated aqueous humor

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